16 Climate Change

Everything should be made as simple as possible, but not simpler.

—Albert Einstein

Introduction

As pollutants flow beyond local boundaries, the political difficulties of implementing comprehensive, cost-effective control measures are compounded. Pollutants crossing boundaries impose external costs; neither emitters nor the political jurisdictions within which they emit have the proper incentives for controlling them.

Compounding the problem of improper incentives is the scientific uncertainty that limits our understanding of these complex problems. Our knowledge about various relationships that form the basis for our understanding of the magnitude of the problems and the effectiveness of various strategies to control them is far from complete. Unfortunately, the problems are so important and the potential consequences of inaction so drastic that procrastination is not usually an optimal strategy. To avoid having to act in the future under emergency conditions when the remaining choices have dwindled, strategies with desirable properties must be formulated now on the basis of the available information, as limited as it may be. Options must be preserved.

The costs of inaction are not limited to the damages caused. International cooperation among such traditional allies as the United States, Mexico, and Canada and the countries of Europe has been undermined by disputes over the proper control of transboundary pollution.

In this chapter we survey the scientific evidence on the effectiveness of policy strategies designed to alleviate the problems associated with climate change. We also consider difficulties confronted by the government in implementing solutions and the role of economic analysis in understanding how to circumvent these difficulties.

The Science of Climate Change

One class of global pollutants, greenhouse gases, absorb the long-wavelength (infrared) radiation from the earth's surface and atmosphere, trapping heat that would otherwise radiate into space. The mix and distribution of these gases within the atmosphere is in no small part responsible for both the hospitable climate on the Earth and the inhospitable climate on other planets; changing the mix of these gases, however, can modify the climate.

Although carbon dioxide is the most abundant and the most studied of these greenhouse gases, many others have similar thermal radiation properties. These include the chlorofluorocarbons, nitrous oxide, and methane.

The current concern over the effect of this class of pollutants on climate arises because emissions of these gases are increasing over time, changing their mix in the atmosphere. Evidence is mounting that by burning fossil fuels, leveling tropical forests, and injecting more of the other greenhouse gases into the atmosphere, humans are creating a thermal blanket capable of trapping enough heat to raise the temperature of the earth's surface.

The Intergovernmental Panel on Climate Change (IPCC), the body charged with compiling and assessing the scientific information on climate change, reported its findings in 2007 on both the sources and likely outcomes of climate change. With respect to the role of humans, they found that most of the warming observed over the last 250 years can, with a very high level of confidence, be attributable to human activity. With respect to projected climatic changes, they found the following:

- The global increases in carbon dioxide concentration are due primarily to fossil-fuel use and land-use change, while those of methane and nitrous oxide are due primarily to agriculture.
- Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level.
- Human-induced warming and sea-level rise would continue for centuries due to the timescales associated with the climate processes and feedbacks, even if greenhouse gases were to be stabilized.
- Projected impacts of the warming include contracting snow cover, shrinking sea ice in the Arctic and Antarctic regions, and increasing weather events such as extreme heat, heavy precipitation and intense storms.

Interestingly, since that report was finalized, new evidence suggests that the warming process may be moving faster than was anticipated in the IPCC report, thereby raising the expected economic damages caused (Stern, 2008).

Recently, scientists have also uncovered evidence to suggest that climate change may occur rather more abruptly than previously thought. Since the rate of temperature increase is a significant determinant of how well ecosystems can adapt to temperature change, abrupt climate change has become a matter of some concern.

An example that raises this concern is the methane trapped in the frozen tundra of the north. Large quantities of methane gas lie trapped in the frozen tundra. As temperatures warm, the tundra can thaw, releasing the trapped methane. Since methane is a powerful greenhouse gas, this release could accelerate the rate of warming.

What are the likely impacts of this combination of rapidly rising temperatures, rising sea levels, and the potential for more frequent and more intense storms? An earlier working group of the panel, tasked with the responsibility to find out, came to several conclusions:[1]

- Recent regional climate changes, particularly temperature increases, have already affected many physical and biological systems.
- Natural systems (including coral reefs, mangroves, and tropical forests) are vulnerable to climate change and some will be irreversibly damaged.
- Developing countries, especially in Africa, are expected to feel the most severe effects of climate change since they will experience multiple stresses and have the fewest resources to commit to adaptation.
- Adaptation is now necessary to address impacts resulting from the warming that is already unavoidable due to past emissions.

These threats pose a significant challenge to our economic and political institutions. Are they up to the challenge? The answer is not clear because significant barriers confront any attempt to move toward a solution. Concepts developed earlier in the text can help us understand both the nature of these barriers and possible strategies for surmounting them.

Any action taken to moderate climate change provides a global public good, implying the strong possibility of free-rider actions. (Those who do not control greenhouse gases cannot be prevented from reaping the benefits of the actions of those who do.) Free-rider effects not only cause emissions to be abnormally high, but they also inhibit investment in research and development, a key ingredient in promoting innovative, low-carbon technologies. Free-rider effects also inhibit the participation of nations in the climate change agreements that are designed to correct these market failures. And unlike a normal marketed good, the scarcity of a stable, hospitable climate is not signaled by rising prices for that good.

To further complicate matters, the damage caused by greenhouse pollutants is an externality in both space and time. Spatially, the largest emitters (the industrialized nations) have the greatest capacity to reduce emissions, but they are not expected to experience as much damage from insufficient actions as the developing countries. Temporally, the costs of controlling greenhouse gases fall on current generations, while the benefits from controlling them occur well into the future, making it more difficult

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[1]The evidence in this section comes from IPCC. James J. McCarthy, Osvaldo F. Canziani, Neil A. Leary, David J. Dokken, and Kasey S. White, eds. *Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge, UK: Cambridge University Press, 2001).

to convince members of the current generation to join the mitigation effort. The implication of these insights is that decentralized actions by markets and individual governments are likely to violate both the efficiency and sustainability criteria. International collective action is both necessary and terribly difficult.

Negotiations over Climate Change Policy

Characterizing the Broad Strategies

What can be done? Three strategies have been identified: (1) climate engineering, (2) adaptation, and (3) mitigation.

Climate engineering or, alternatively, *geoengineering* approaches can be divided into two very different categories: carbon dioxide removal and solar-radiation management. While approaches in the former category, such as direct air capture or ocean fertilization, seek to reduce the greenhouse gases, approaches in the second category, such as injecting stratospheric aerosols, aim to cool the planet by reflecting a fraction of the incoming sunlight away from Earth. Some propose that one or more of these strategies could provide a cost-effective alternative to mitigation, but recent other reviews have emphasized that such approaches are fraught with uncertainties and may have potential adverse effects and, thus, cannot currently be considered a substitute for comprehensive mitigation. Research continues, while the ultimate role for geoengineering remains to be determined.

Adaptation strategies involve efforts to modify natural or human systems in order to minimize harm from climate change impacts. Examples include modifying development planning to include the impacts of sea-level rise and preparing public health facilities to handle the consequences of the changing disease impacts of a warmer climate.

Mitigation attempts to moderate the temperature rise by using strategies designed to reduce emissions or increase the planet's natural capacity to absorb greenhouse gases. In this chapter we shall focus mainly on mitigation.

The most significant mitigation strategy deals with our use of fossil-fuel energy. Combustion of fossil fuels results in the creation of carbon dioxide. Carbon dioxide emissions can be reduced either by using less energy or by using alternative energy sources (such as wind, photovoltaics, or hydro) that produce no carbon dioxide. Any serious reduction in carbon dioxide emissions would involve significant changes in our energy-consumption patterns and could have a high economic cost. Thus, the debate over how vigorously this strategy is to be followed is a controversial public-policy issue.

Another possible strategy involves encouraging activities that increase the amount of carbon that is absorbed by trees or soils. As Debate 16.1 points out, however, the desirability of this approach is heavily debated in current climate change negotiations.

Finding a global solution to climate change is certainly one of the most challenging and pressing problems of our time, but it is not the first global pollutant to be the subject of international negotiations. The negotiations aimed at reducing ozone-depleting gases broke the ice.

DEBATE 16.1

Should Carbon Sequestration in the Terrestrial Biosphere Be Credited?

Both forests and soils sequester (store) a significant amount of carbon. Research suggests that with appropriate changes in practices, they could store much more. Increased *carbon sequestration* in turn would mean less carbon in the atmosphere. Recognition of this potential has created a strong push in the climate change negotiations to give credit for actions that result in more carbon uptake by soils and forests. Whether this should be allowed, and, if so, how it would be done are currently heavily debated.

Proponents argue that this form of carbon sequestration is typically quite cost-effective. Cost-effectiveness not only implies that the given goal can be achieved at lower cost, but also it may increase the willingness to accept more stringent goals with closer deadlines. Allowing credit for carbon absorption may also add economic value to sustainable practices (such as limiting deforestation or preventing soil erosion), thereby providing additional incentives for those practices. Proponents further point out that many of the prime beneficiaries of this increase in value would be the poorest people in the poorest countries.

Opponents say that our knowledge of the science of carbon sequestration in the terrestrial biosphere is in its infancy, so the amount of credit that should be granted is not at all clear. Obtaining estimates of the amount of carbon sequestered could be both expensive (if done right) and subject to considerable uncertainty. Because carbon absorption could be easily reversed at any time (by cutting down trees or changing agricultural practices), continual monitoring and enforcement would be required, adding even more cost. Even in carefully enforced systems, the sequestration is likely to be temporary (even the carbon in completely preserved forests, for example, may ultimately be released into the atmosphere by decay). And finally, the practices that may be encouraged by crediting sequestration will not necessarily be desirable, as when slow-growing old-growth forests are cut down and replaced with fast-growing plantation forests in order to increase the amount of carbon uptake.

The Precedent: Reducing Ozone-Depleting Gases

In the stratosphere, the portion of the atmosphere lying just above the troposphere, rather small amounts of ozone present have a crucial positive role to play in determining the quality of life on the planet. In particular, by absorbing the ultraviolet wavelengths, stratospheric ozone shields people, plants, and animals from harmful radiation, and by absorbing infrared radiation, it is a factor in determining the earth's climate.

Chlorofluorocarbons (CFCs), which are greenhouse gases, also deplete the stratospheric ozone shield as a result of a complicated series of chemical reactions. These chemical compounds are used as aerosol propellants and in cushioning foams, packaging and insulating foams, industrial cleaning of metals and electronics components, food freezing, medical instrument sterilization, refrigeration for homes and food stores, and air-conditioning of automobiles and commercial buildings.

The major known effect of the increased ultraviolet radiation resulting from *tropospheric ozone depletion* is an increase in nonmelanoma skin cancer. Other potential effects, such as an increase in the more serious melanoma form of skin cancer, suppression of human immunological systems, damage to plants, eye cancer in cattle, and an acceleration of degradation in certain polymer materials, are suspected but not as well established.

Responding to the ozone-depletion threat, an initial group of 24 nations signed the *Montreal Protocol* in September 1988. A series of new agreements followed that generally broadened the number of covered substances and established specific schedules for phasing out their production and use. Currently, some 96 chemicals are controlled by these agreements to some degree.

The protocol is generally considered to have been a noteworthy success. As of 2008, more than 95 per cent of ozone-depleting substances have been phased out and the ozone layer is expected to return to its pre-1980 levels no later than 2075.

Part of the reason for the success of this approach was an early recognition of the importance of the need to solicit the active participation of developing countries. One component of the success in eliciting that participation resulted from offering later phaseout deadlines for developing countries. Another important aspect involved the creation of a Multilateral Fund.

In 1990 the parties agreed to establish the *Multilateral Fund*, which was designed to cover the incremental costs that developing countries incur as a result of taking action to eliminate the production and use of ozone-depleting chemicals. Contributions to the Multilateral Fund come from the industrialized countries. The fund has been replenished seven times. As of July 2008, the contributions made to the Multilateral Fund by some 49 industrialized countries, including Countries with Economies in Transition (CEIT), totaled more than $2.4 billion.

The fund promotes technical change and facilitates the transfer of more environmentally safe products, materials, and equipment to developing countries. It offers developing countries that have ratified the agreement access to technical expertise, information on new replacement technologies, training and demonstration projects, and financial assistance for projects to eliminate the use of ozone-depleting substances.

The existence of the Multilateral Fund, however, does not deserve all the credit for the success of the Montreal Protocol. The success of ozone protection has been possible in no small measure because producers were able to develop and commercialize alternatives to ozone-depleting chemicals. Countries and producers ended the use of CFCs faster and cheaper than was originally anticipated due to the availability of these substitutes.

Although the agreements specify national phasedown targets, it is up to the countries to design policy measures to reach those targets. The United States chose a unique combination of product charges and tradable allowances to control the production and consumption of ozone-depleting substances (see Example 16.1). Most observers believe this combination was highly effective in encouraging the transition away from ozone-depleting substances.

EXAMPLE 16.1

Tradable Allowances for Ozone-Depleting Chemicals

On August 12, 1988, the U.S. Environmental Protection Agency issued its first regulations implementing a tradable allowance system to achieve the targeted reductions in ozone-depleting substances. According to these regulations, all major U.S. producers and consumers of the controlled substances were allocated baseline production or consumption allowances, using 1986 levels as the basis for the proration. Each producer and consumer was allowed 100 percent of this baseline allowance initially, with smaller allowances granted after predefined deadlines. Following the London conference, these percent-of-baseline allocations were reduced in order to reflect the new, earlier deadlines and lower limits.

These allowances are transferable within producer and consumer categories, and allowances can be transferred across international borders to producers in other signatory nations if the transaction is approved by the EPA and results in the appropriate adjustments in the buyer or seller allowances in their respective countries. Production allowances can be augmented by demonstrating the safe destruction of an equivalent amount of controlled substances by an approved means. Some interpollutant trading is even possible within categories of pollutants. (The categories are defined so as to group pollutants with similar environmental effects.) All information on trades is confidential (known only to the traders and the regulators), which makes it difficult to know how effective this program has been.

Since the demand for these allowances is quite inelastic, supply restrictions increase revenue. Because of the allocation of allowances to the seven major domestic producers of CFCs and halons, the EPA was concerned that its regulation would result in sizable windfall profits (estimated to be in the billions of dollars) for those producers. The EPA handled this problem by imposing a tax on production in order to "soak up" the rents created by the regulation-induced scarcity.

This application was unique in two ways. It not only allowed international trading of allowances, but also it involved the simultaneous application of tradable allowance and tax systems. Taxes on production, when coupled with allowances, have the effect of lowering allowance prices. The combined policy, however, is no less cost-effective than allowances would be by themselves, and it does allow the government to acquire some of the rent that would otherwise go to allowance holders.

Source: Tom Tietenberg, "Design Lessons from Existing Air Pollution Control Systems: The United States." PROPERTY RIGHTS IN A SOCIAL AND ECOLOGICAL CONTEXT: CASE STUDIES AND DESIGN APPLICATIONS by S. Hanna and M. Munasinghe, eds. (Washington, DC: World Bank, 1995), pp. 15–32.

More recently, attempts have been made internationally to use this agreement as the basis for phasing out hydrofluorocarbons (HFCs), one class of chemicals used to replace the CFCs, because they also turn out to be powerful greenhouse gases. Along with Mexico and Canada, the United States has proposed a series of steps to reduce HFC production, with wealthier countries not only facing a quicker deadlines than developing nations, but also providing financing for poorer countries to adopt substitutes. The Environmental Protection Agency estimates that adopting the HFC proposal could slow global warming by a decade.

The Policy Focus of the Climate Change Negotiations

Early in climate change negotiations it became clear that mitigation by means of cost-effective strategies was a priority. For reasons explained in Chapter 15, the policy choices quickly narrowed down to emissions charges and cap-and-trade. In general, Europe tended to favor carbon taxes, while the United States preferred cap-and-trade.

Designing a carbon tax could be particularly simple in the climate change case. Because greenhouse gases are uniformly mixed pollutants, a uniform per-unit charge imposed on all emissions sources would be cost-effective. And putting a tax on pollution could be expected not only to encourage new, more environmentally benign technologies, but also to raise significant revenue. In addition, the use of taxes could assure more stable carbon prices.

Ease of design, however, was not the only consideration. Concerns about carbon taxes arose when it became clear that the amount of revenue collected from these taxes would be very large. The concept of taxes imposed by some international authority (who would then have control over all that revenue) was soon replaced by a concept relying on harmonized national taxes where the revenue would stay in the nation that collected it. Nations were not the only ones concerned about the magnitude of tax revenues; firms were also concerned about the financial burden those taxes would impose on them. Simply knowing that the revenue would be kept by their national governments was generally not enough to overcome these business concerns.

Concerns over the magnitude and distribution of the revenue were soon joined by concerns over the consequences of participating in a system that taxed only some of the parties. The United States made it clear that it was very reluctant to go along with emissions charges. And it is not clear that developing countries should (or would) be asked to bear these charges, at least in the early years of control. A system of partial taxation could lead to leakage (offsetting greenhouse gas emissions from nonparticipating countries) and to significant competitiveness issues.

Leakage can occur when taxed producers try to pass on their additional costs to consumers. If consumers have the choice of importing products from producers in nations with no emissions charges, they are inclined to favor those imports over domestic (taxed) products because they are likely to cost less. Meanwhile, producers in the taxed nations, once they notice their market share being eroded by competitors in the untaxed nations, have an incentive to relocate their production facilities to the untaxed nations to take advantage of the lower costs. Ultimately, not only could the taxed nations lose production and jobs, but also total greenhouse gases could increase if the reduction in the taxed nations is more than offset by increases in the untaxed nations.

The emphasis began to shift toward cap-and-trade. In one of the interesting ironies of climate change policy, the Kyoto Protocol, the main international agreement controlling greenhouse gases, specifically incorporates three tradable allowance programs, but its prime proponent, the United States, by its failure to ratify the agreement, lost its right to participate (except as an outside observer) in the design, evolution, and use of that system.

The Evolution of International Agreements on Climate Change

The 1992 United Nations Framework Convention on Climate Change (UNFCCC) recognized the principle of global cost-effectiveness of emissions reduction and thus opened the way for flexibility. Since this early agreement did not fix a binding emissions target for any country, the need to invest in emissions reduction either at home or abroad was not pressing.

However, in December 1997 industrial countries and countries with economies in transition (primarily the former Soviet Republics) agreed to legally binding emissions targets at the Kyoto Conference and negotiated a legal framework as a protocol to the UNFCCC—the Kyoto Protocol. This protocol became effective in February 2005 once at least 55 parties representing at least 55 percent of the total carbon dioxide (CO_2) emissions had ratified. Russia's ratification put the protocol over the 55 percent total; the 55-country total had been reached much earlier.

The Kyoto Protocol defines a five-year commitment period (2008–2012) for meeting the individual country emissions targets, called "assigned amount obligations," set out in Annex B of the Protocol. Quantified country targets are defined by multiplying the country's 1990 emissions level by a reduction factor and multiplying that number by 5 (to cover the five-year commitment period). Collectively, if fulfilled, these targets would represent a 5 percent reduction in annual average emissions below 1990 levels for the participating parties. The actual compliance target is defined as a weighted average of six greenhouse gases: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride. Defining the target in terms of this multigas index, rather than just carbon dioxide, has been estimated to reduce compliance costs by some 22 percent (Reilly et al., 2002).

The Intergovernmental Panel on Climate Change reviewed a host of studies to find out what difference allowance trading would make on costs and concluded that it would typically cut the costs in half.

How large are the resulting costs? These studies predict that the effect of controlling climate change is to slow growth, but not to stop or reverse it. As Azar and Schnieder (2002) point out, one way to contextualize the cost of stabilizing emissions in the 350–550 ppm range is to recognize that the cost involves a one-to three-year delay in reaching the new higher wealth level.

The Kyoto Protocol authorizes three cooperative implementation mechanisms that involve tradable allowances: Emission Trading, Joint Implementation, and the Clean Development Mechanism (CDM).

- "Emissions Trading" (ET), a cap-and-trade policy, allows trading of "assigned amounts" (the national quotas established by the Kyoto Protocol) among countries listed in Annex B of the Kyoto Protocol, primarily the industrialized nations and the economies in transition.
- Under "Joint Implementation" (JI), Annex B Parties can receive emissions reduction credit when they help to finance specific projects that reduce

net emissions in another Annex B Party country. This "project-based" program is designed to exploit opportunities in Annex B countries that have not yet become fully eligible to engage in the ET program described above.

- The "Clean Development Mechanism" enables Annex B Parties to finance emissions reduction projects in non–Annex B Parties (primarily developing countries) and receive certified emissions reductions (CERs) for doing so. These CERs can be used to fulfill "assigned amount" obligations.

These programs have, in turn, spawned others. Despite the fact that the United States has not signed the Kyoto Protocol, some American states have accepted mandatory caps on CO_2 and are using trading to facilitate meeting those goals.

The largest and most important of the existing programs is the cap-and-trade system developed by the European Union to facilitate implementation of the Kyoto Protocol (see Example 16.2).

EXAMPLE 16.2

The European Union Emissions Trading System (EU ETS)

The EU ETS applies to 25 countries, including the 10 "accession" countries, most of which are former members of the Soviet bloc. The first phase, which ran from 2005 through 2007, was considered to be a trial phase. The second phase coincides with the first Kyoto commitment period, beginning in 2008 and continuing through 2012. Subsequent negotiations will specify the details of future phases.

Initially, the program covers only carbon dioxide (CO_2) emissions from four broad sectors: iron and steel, minerals, energy, and pulp and paper. All installations in these sectors that are larger than established thresholds are included in the program. More than 12,000 installations are covered by the program, making it the largest emissions trading program ever established.

The allocation scheme provides installations with gifted allowances. Gifting the allowances turned out in the light of experience to result in inflated profits in the utility sectors, a fact that has helped propel the movement toward auctions in more recent programs such as the Regional Greenhouse Gas Initiative in the northeastern United States (see Example 14.4).

Countries can use emissions reductions acquired from outside the European Union (via the JI or CDM mechanisms) to meet their obligations under the *European Union Emissions Trading Scheme*. Estimates by Criqui and Kitous (2003) indicate that allowing unrestricted trades among all these options could reduce compliance cost by about 24 percent.

Sources: J. A. Kruger and William A. Pizer, "Greenhouse Gas Trading in Europe: The New Grand Policy Experiment." ENVIRONMENT, Vol. 46, No. 8 (2004), pp. 8–23; and P. Criqui and A. Kitous, "Kyoto Protocol Implementation: (KPI) Technical Report: Impacts of Linking JI and CDM Credits to the European Emissions Allowance Trading Scheme, CNRS-IEPE and ENERDATA S.A. for Directorate General Environment," Service Contract No. B4-3040/2001/330760/MAR/E1 (2003) as cited in Kruger and Pizer (2004, Table 2).

While the emissions trading mechanism is the driving force behind the suite of cooperative mechanisms, the CDM provides a means for motivating industrialized countries (or individual companies) to invest in projects in developing countries that result in reductions of greenhouse gases. The incentive to invest is provided by the fact that investors can receive credit for the reductions that are "additional" to reductions that would have been achieved otherwise. Once verified and certified, these credits can then be used as one means of meeting the investor's "assigned amount" obligation. The incentive for the host developing countries to participate comes from the fact that many of these projects increase productivity while reducing emissions. Projects that replace old coal-burning power plants with newer facilities based on photovoltaics or natural gas illustrate the point.[2]

Complementary Strategies

Given the problems associated with identifying promising projects, quantifying the magnitude of the reductions, and monitoring the results, some means of reducing those barriers was clearly called for. In response, the Prototype Carbon Fund (PCF) was established in 1999 by the World Bank to serve as an intermediary for encouraging CDM reductions in greenhouse gases (http://wbcarbonfinance.org/Router.cfm?Page=PCF). The PCF, which acts as a kind of greenhouse gas mutual fund, invests contributions made by companies and governments in projects designed to produce emissions reductions that are consistent with the Kyoto Protocol. Investors in the PCF receive a pro rata share of the emissions reductions. These reductions are verified and certified in accordance with agreements reached with the respective countries hosting the projects.

Another complementary agency, the Global Environmental Facility (GEF), has begun to play an important role in funding deserving projects (http://www.globalenvironmentfund.com/). Drawing from a Global Environmental Trust Fund, funded by direct contributions from some 26 countries, the GEF provides loans and grants to projects that have a global impact, including projects that reduce climate change.

Recognizing that many projects have benefits that flow beyond national borders, and that individual nations are unlikely to consider those global benefits, the GEF picks up the *marginal external costs*, the costs that cannot be justified domestically, but could be justified internationally. For example, suppose building a coal-fired power plant is the cheapest way for China to provide electricity to its people, but a slightly more expensive wind power plant would result in substantially lower carbon dioxide emissions. Since the benefits from lower carbon dioxide emissions are largely global, not national, China has little incentive to consider them in its decision; the coal-fired plant would be

[2]Further information on both the CDM process and the projects that are flowing from it can be found at http://cdm.unfccc.int/index.html.

chosen. By picking up the extra cost for the wind facility, the GEF can increase the attractiveness of the alternative facility and thereby ensure that China's decision makes sense globally as well as nationally.

Controversies

Emissions trading is not without its problems. Controversies range from such fundamental issues as the morality of global emissions trading (see Debate 16.2) to concerns about weaknesses in the implementation details.

Two particular perceived implementation deficiencies have received considerable attention. First, greenhouse gas emissions trading will only achieve the goals of the Protocol if monitoring and enforcement is adequate. Monitoring and enforcing international agreements is much more difficult than enforcing domestic laws and regulations. Effective monitoring and enforcement in this international context is far from a foregone conclusion. Second, due to the way the goals of the Protocol were specified, some countries (specifically Russia and the Ukraine) find

DEBATE 16.2

Is Global Greenhouse Gas Trading Immoral?

In a December 1997 editorial in *The New York Times,* Michael Sandel, a Harvard government professor, suggested that greenhouse gas trading is immoral. He argues that treating pollution as a commodity to be bought and sold not only removes the moral stigma that is appropriately associated with polluting, but also trading reductions undermines an important sense of shared responsibilities that global cooperation requires. He illustrated the point by suggesting that legitimizing further emission by offsetting it with a credit acquired from a project in a poorer nation would be very different from penalizing the firm for emitting, even if the cost of the credit were equal to the penalty. Not only would the now-authorized emission become inappropriately "socially acceptable," but also the wealthier nation would have met its moral obligation by paying a poorer nation to fulfill a responsibility that should have been fulfilled by a domestic emissions reduction.

Published responses to this editorial countered with several points. First, it was pointed out that since it is voluntary, international emissions trading typically benefits both nations; one nation is not imposing its will on another. Second, the historical use of these programs has resulted in much cleaner air at a much lower cost than would otherwise have been possible, so the ends would seem to justify the means. Third, with few exceptions, virtually all pollution-control regulations allow some emission that is not penalized; this is simply a recognition that zero pollution is rarely either efficient or politically feasible.

Source: Michael J. Sandel, "It's Immoral to Buy the Right to Pollute" with replies by Steven Shavell, Robert Stavins, Sanford Gaines, and Eric Maskin. THE NEW YORK TIMES, December 17, 199; excerpts reprinted in Robert N. Stavins, ed. Economics of the Environment: Selected Readings, 4th ed. (New York: W.W. Norton & Company, 2000) pp. 449–452.

themselves with a considerable number of "unearned" surplus allowances to sell. (Since Protocol requirements are defined in terms of 1990 emissions levels and emissions in these countries have fallen below those levels due to the depressed state of their economies, the difference, known popularly as "hot air," can be traded to other countries.) The presence of these surplus allowances naturally lowers prices and allows countries to undertake less domestic abatement than would otherwise have been necessary.

Policy Timing

What is the optimal level of current investments in greenhouse gas reduction? In order to answer this question, we must first discover just how serious the problem is and then ascertain the costs of being wrong, either by acting too hastily or by procrastinating. Because uncertainties are associated with virtually every link in the logical chain from human activities to subsequent consequences, we cannot at this juncture state unequivocally how serious the damage will be. We can, however, begin to elaborate the range of possibilities and see how sensitive the outcomes are to the choices before us.

Benefit–cost studies of options for controlling climate change that ignore uncertainties in the state of our knowledge typically suggest a "go slow" or "wait-and-see" policy. The reasons for these results are instructive. First, the benefits from current control are experienced well into the future, while the costs occur now. The present-value criterion in benefit–cost analysis discounts future values more than current values. Second, both energy-using and energy-producing capital are long-lived. Replacing them all at an accelerated pace now would be more expensive than replacing them over time closer to the end of their useful lives. Third, the models anticipate that the number of new emissions-reducing technologies would be larger in the future and, due to this larger menu of options, the costs of reduction would be lower with delay.

The use of benefit–cost analysis based upon the present-value criterion in climate change discussion is controversial. Although this approach is not inherently biased against future generations, their interests will only be adequately protected if they are adequately compensated for the damage inflicted on them either by higher incomes or actual compensation. Because it is not obvious that growth in per capita well-being would be adequate, the long lead times associated with this particular problem place the interests of future generations in maintaining a stable climate in jeopardy, raising an important ethical concern (Portney and Weyant, 1999).

The other reasons have economic merit, but they do not necessarily imply a "wait-and-see" policy. Spreading the capital investment decisions over time implies that some investments take place now as current capital is replaced. Furthermore, the expectation that future technical change can reduce costs will only be fulfilled if the incentives for producing the technical change are in place now. In both cases, waiting simply postpones the process of change.

Another powerful consideration in the debate over the timing of control investments involves uncertainty about both the costs and the benefits of climate change. Governments must act without complete knowledge. How can they respond reasonably to this uncertainty?

The risks of being wrong are clearly asymmetric. If it turns out that we controlled more than we must, current generations would bear a larger-than-necessary cost. On the other hand, if the problem turns out to be as serious as the worst predictions indicate, catastrophic and largely irreversible damage to the planet could be inflicted on future generations.

Yohe, Andronova, and Schlesinger (2004) investigate both consequences of being wrong using a standard, well-respected global climate model. Their model assumes that decision makers choose global mitigation policies in 2005 that will be in effect for 30 years, but that in 2035 policy-makers would be able to modify the policies to take into account the better understanding of climate change consequences that would have afforded by the intervening 30 years. The specific source of uncertainty in their model results from our imperfect knowledge about the relationship between the atmospheric greenhouse gas concentrations and the resulting change in climate impacts. The specific question they examine is, "What is the best strategy now?"

They find that a hedging strategy that involves modest reductions now dominates a "wait-and-see" strategy. Not only does current action initiate the capital turnover process and provide incentives for technical change, but also it allows the avoidance of very costly and potentially irreversible mistakes later. Since emissions from the "wait-and-see" strategy would be much higher by 2035, the reductions necessary to meet a given concentration target would have to be not only larger, but also concentrated within a smaller period of time. If in 2035, for example, scientists discover the need to stabilize greenhouse gas concentrations at a more stringent level to avoid exceeding important thresholds (such as the methane examples discussed previously), that may not only be much more difficult and much more expensive to do later, but it may be impossible (because it would be too late).

Creating Incentives for Participation in Climate Change Agreements

Since ratifying any climate change agreement is a voluntary act, the branch of economics known as game theory has been used to study what mechanisms can be used to encourage participation in light of the serious free-rider problems they face (Barrett, 1990). This is a productive analytical undertaking because it demonstrates that the free-rider problem is not necessarily a fatal flaw in the search for solutions to the climate change problem (Carraro, 2002).

One strategy that we have already discussed, the use of cost-effective policies, can positively affect the level of participation. Since cost-effective policies reduce the cost, but not the benefits, of participation, those policies should make participation more likely by increasing the net benefits from joining the agreement.

Another strategy involves "issue linkage" in which countries simultaneously negotiate a climate change agreement and a linked economic agreement. Typical candidates for linkage are agreements on trade liberalization, cooperation on research and development (R&D), or international debt. The intuition behind this approach is that some countries gain from resolving the first issue, while others gain from the second. Linking the two issues increases the chances that cooperation may result in mutual gain and, hence, increases the incentives to join the coalition of those ratifying the climate change agreement.

To understand how this works, consider a research-and-development example from Cararro (2002). To counteract the incentive to free ride on the benefits from climate change, suppose only ratifiers of both agreements share in the insights gained from research and development in the ratifying countries. The fact that this benefit can only be obtained by ratifying both the climate change agreement and the R&D agreement provides an incentive to ratify both. Since those nations choosing not to ratify can be excluded from the research-and-development benefits, to obtain those benefits, they would have to join the agreement.

Another strategy for encouraging participation involves transfers from the gainers to the losers. Some countries have more to gain from an effective agreement than others. If the gainers were willing to share some of those gains with reluctant nations who have more to lose, the reluctant nations could be encouraged to join. Some interesting work (Chandler and Tulkens, 1997) has shown that it is possible to define a specific set of transfers such that each country is better off participating than not participating. That is a powerful, comforting result.

In terms of operationalizing this concept of using transfers as an inducement to join the agreement, the Bali Climate Change Conference in 2007 established a funding mechanism for adaptation, which could generate up to $300 million over 2008–2012. It was established to finance concrete adaptation projects and programs in developing countries that are Parties to the Kyoto Protocol (http://www.adaptation-fund.org). The Fund, which falls under the auspices of the Global Environmental Facility, is to be financed primarily from a 2 percent levy on proceeds from Clean Development Mechanism projects. Note that while this fund is directed toward adaptation, rather than mitigation, the fact that it is available only to parties to the agreement provides an incentive for nonsignatories to participate.

Summary

The first global pollutant problem confronted by the international community arose when ozone-depleting gases were implicated in the destruction of the stratospheric ozone shield that protects the earth's surface from harmful ultraviolet radiation. Because these are accumulating pollutants, an efficient response to this problem involves reducing their emissions over time. In principle, this could be accomplished by either an emissions charge that rises over time or an allowance system that allows a fixed amount of emissions.

To restrict their accumulation in the atmosphere, the international agreements on ozone-depleting substances created a system of limits on production and consumption. As part of its obligation under the agreements, the United States adopted a transferable allowance system, coupled with a tax on the additional profits generated when the supply of allowances was restricted. Internationally, this system is considered a success in no small part because the Multilateral Fund and other incentives, such as delayed compliance deadlines, facilitated the participation of developing countries.

Climate change is appropriately considered a more difficult problem to solve than ozone depletion. In addition to the features it shares with ozone depletion, such as the free-rider problem, and the fact that the current generation bears the costs while the benefits accrue in the future, climate change presents some unique challenges. Some countries, for example, may be benefited, not harmed, by climate change, diminishing even further their incentive to control. And in contrast to ozone-depleting substances, which had readily available substitutes, controlling greenhouse gases means controlling energy use from fossil fuels, the lynchpin of modern society.

Fortunately, economic analysis of the climate change problem not only defines the need for action, but also sheds light on effective forms that action might take. The empirical studies suggest that it makes sense to take action now to reduce emissions of greenhouse gases in order to provide insurance against the adverse, possibly irreversible consequences if the damage turns out to be higher than anticipated. Although policies in the Kyoto Protocol, such as the emissions trading program, joint implementation, and the clean development mechanism, use basic economic concepts to forge practical, cost-effective means of controlling climate change, we have also seen that the implementation details matter.

Economics also sheds light on the barriers to effective participation in climate change agreements and some potential solutions as well. The free-rider effect is a significant barrier to participation, but strategies that flow from game theory (such as international transfers and issue linkage) can be used to build incentives for participation. Some international cost sharing is likely to be as necessary an ingredient in a successful attack on the climate problem as it was in the ozone-depletion case.

During the next few decades, options must not only be preserved, they must be enhanced. Responding in a timely and effective fashion to global and regional pollution problems will not be easy. Our political institutions are not configured in such a way as to make decision making on a global scale simple. International organizations exist at the pleasure of the nations they serve. Only time will tell if the mechanisms of international agreements described in this chapter will prove equal to the task.